Public Quarterly Report

Date of Report: 6th Quarterly Report-January 30, 20
Contract Number: 693JK31810001
Prepared for: DOT
Project Title: Improvements to Pipeline Assessment Methods and Models to Reduce Variance
Prepared by: GTI
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For quarterly period ending: October 30, 2019

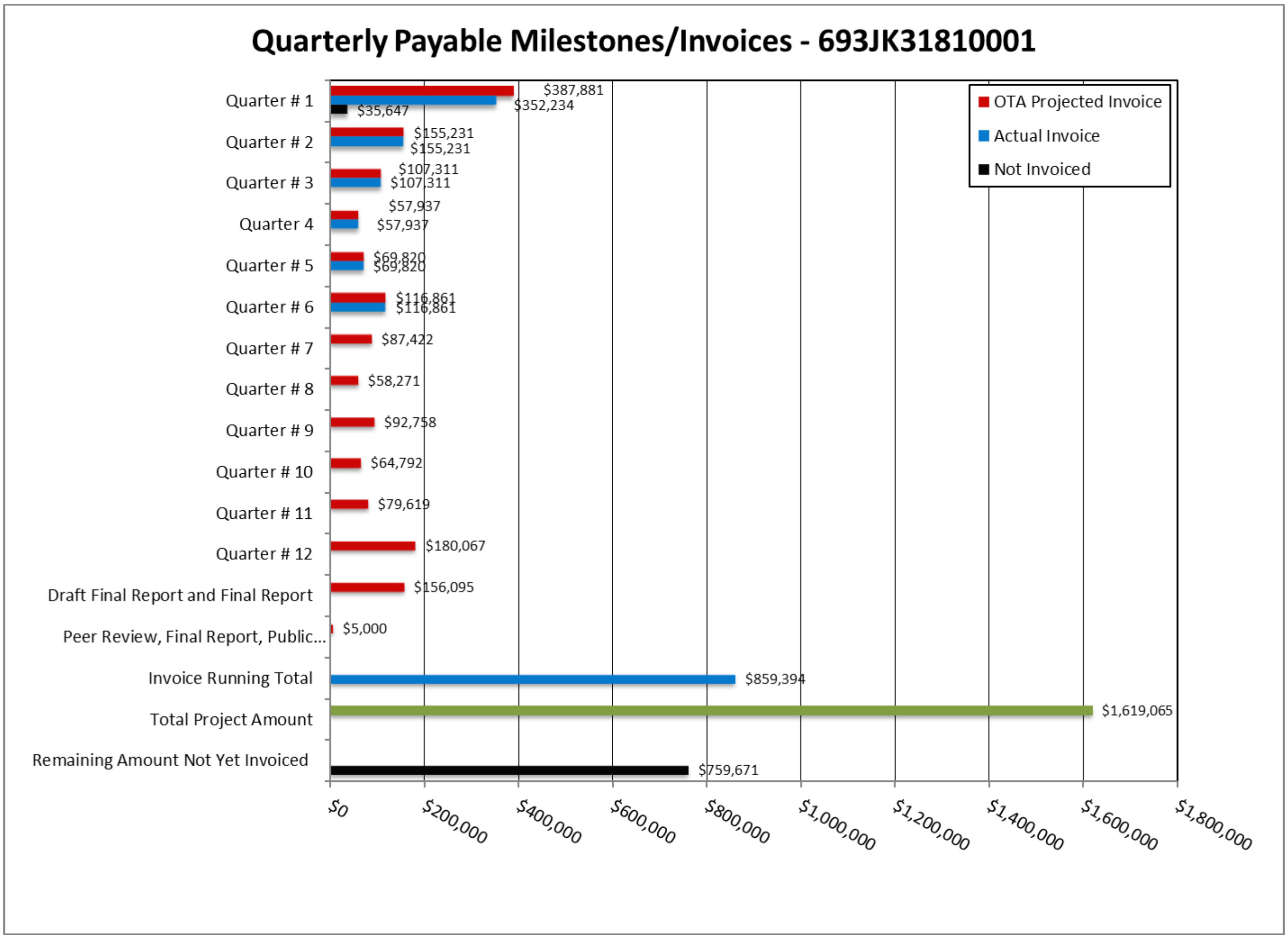
1: Items Completed During this Quarterly Period:

Item #	*Task #*	*Activity/Deliverable*	*Title*	*Federal Cost*	*Cost Share*
42	3.2.1.2	Uncertainty Reduction	Probabilistic Fracture Assessment Phase 4 Report	$25,537	$-
43	4.2.2	Structural FEM Study	FEM DoE Phase 4 Report	$14,908	$-
44	5.2.1.2	FEM Simulation of NDE Signal Responses	Model-based Framework Phase 4 Report	$20,501	$-
45	7.2.1	Full Scale Pipe Testing	Full Scale Pipe Testing Report	$50,220	$-
46	9.2.2	Project Management	6th Quarterly Report	$5,695	$-

2: Items Not Completed During this Quarterly Period:

Item #	*Task #*	*Activity/Deliverable*	*Title*	*Federal Cost*	*Cost Share*
NA	NA	NA	NA	NA	NA

3: Project Financial Tracking During this Quarterly Period:



The invoice that will be submitted will include the following line items:

Item #	*Task #*	*Activity/Deliverable*	*Title*	*Federal Cost*	*Cost Share*
42	3.2.1.2	Uncertainty Reduction	Probabilistic Fracture Assessment Phase 4 Report	$ 25,537	$ -
43	4.2.2	Structural FEM Study	FEM DoE Phase 4 Report	$ 14,908	$ -
44	5.2.1.2	FEM Simulation of NDE	Model-based Framework Phase 4 Report	$ 20,501	$ -
45	7.2.1	Full Scale Pipe Testing	Full Scale Pipe Testing Report	$ 50,220	$ -
46	9.2.2	Project Management	6th Quarterly Report	$ 5,695	$ -
			Total	$ 116,861	$ -

4: Project Technical Status

The project technical work continues to progress as planned. The executive summary from each of the detailed task updates, that appear below, are pasted in this section for convenience.

Item # 42, Task # 3.2.1.2, Uncertainty Reduction, Probabilistic Fracture Assessment Phase 4 Report

This report summarizes the work done by ASU during the 6th quarter period, which is mainly focusing on the Bayesian updating for the probabilistic fracture assessment. The deliverable for Task 3.2.2.2 Uncertainty Reduction: Probabilistic Fracture Assessment Phase 4 is completed.

The fracture failure probability is estimated by the efficient active kriging model. The computational cost can be reduced significantly by replacing the time-consuming finite element simulation model with the numerical surrogate model. The active learning procedure can select the most relevant training data related to the accuracy of the final probability. So the accurate surrogate model can be built with the minimum number of training samples. The fracture model (or limit state function) is defined by the stress triaxiality and the equivalent strain to fracture. A fracture locus was constructed according to the experimental and simulation results. The stress triaxiality and the equivalent strain to fracture are dependent on the material or specimen properties. In the current stage, they are assumed to be polynomial functions of several factors. In the future, these quantities will be calculated by the fully developed finite element model.

Increasing amounts of data on engineering systems are available due to various sensor technology advancement. The data (or information) can be used to reduce the uncertainty in engineering models and optimize the management of systems. An effective framework for combining new information with existing models is provided using Bayesian updating technique, in which prior probabilistic models are updated with data and observations. The Bayesian framework enables the combination of uncertain and incomplete information with models from different sources and provides probabilistic information on the accuracy of the updated model. The updated information can then affect the probabilistic risk analysis results. Thus, the probabilistic fracture assessment in the report is performed by both the probabilistic risk analysis and the Bayesian inference. This is a preliminary feasibility study and only synthetic examples are illustrated to show the methodology.

Item # 43, Task # 4.2.2, Structural FEM Study, FEM DoE Phase 4 Report

This report summarizes the work done by MSU during this reporting period, which is mainly focusing on the uncertainty quantification due to physics-based uncertainties in the data fused (MFL-PEC) model. During the 6^{th} quarter, the Task 5.1.1.4 with deliverable, FEM Simulation of NDE signal: Model-based Framework Phase 4 is completed.

On changing the mesh size and the physics governing it, how the uncertainty is varying is displayed in this quarter for the interacting threats. An exhaustive study of the interacting threats based on COMSOL modelling has been developed here. Moreover, to study the interacting threats, instead of taking all the data points, by performing under sampling based on some random points and then have performed Kriging on those data points to predict the interaction among the threats. Kriging is a statistical method that uses a limited set of sampled data points to estimate the value of a variable over a continuous spatial field. Thus, Kriging is a spatial prediction technique that depends on the spatial-temporal relationship among the points in the x and y co-ordinates. Here we are evaluating the magnetic flux distribution as a function of locations. Predicting accurate flux distribution from a smaller number of points will reduce the cost of performing scans throughout the length of entire pipeline, thereby saving computational cost in simulations too.

Item # 44, Task # 5.2.1.2, FEM Simulation of NDE Signal Responses, Model-based Framework Phase 4 Report

In the 6^{th} quarter, GTI made an important step forward with the FEM steel material model with the addition of an elastic damage model. The elastic damage model allows FEM simulations to capture damage initiation and/or propagation in cases where there is no significant bulk plastic deformation, such as a thin edge crack or microstructural flaw (e.g. welds). The elastic damage model is formulated to have a scalar factor, phi, that can be adjusted to reduce the effective ductility of the material, and can be calibrated empirically.

Following on the TAP's interest in crack/weld interactions, preliminary models of welds utilizing the linear damage model were created to explore the influence range of weak welds and the influence of varying the phi factor together with weld strength mismatch. The results from these models showed that varying the phi factor in appropriate material domains is a viable approach to modeling weld strength variability.

Item # 45, Task # 7.2.1, Full Scale Pipe Testing Report

The full-scale testing scope was completed with three additional pipe burst tests: one with a thin axial slit, one with a thin circumferential slit, and one control pipe without machined flaws. FEM simulation of these test cases, utilizing the updated steel material model, over predicted the burst pressure by 8-20%. Additional material calibration is expected to improve the accuracy of the FEA predictions. Although further testing will be required to increase the accuracy of damage model calibrations, the steel model that has been developed thus far provides a very good basis for developing methods to reduce uncertainties in simulations. Moreover, the addition of the elastic damage model and phi factor will allow for case-by-case empirical calibrations of the damage model.

Item # 46, Task # 9.2.2, Project Management, 6th Quarterly Report

All project management reporting requirements have been met.

5: Project Schedule –

All deliverables scheduled for completion in the sixth quarter were completed as scheduled.

End Project Status Update
